

Prepared for:
ALBERTA ENVIRONMENT
EARTH SCIENCES DIVISION - SOILS BRANCH

HYDROGEOLOGY OF THE
WINDY LAKE SITE
SUMMARY REPORT

A Site Evaluation for the
Proposed
SPECIAL WASTE MANAGEMENT FACILITY

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TABLE OF CONTENTS

SECTION ONE - INTRODUCTION	1
SECTION TWO - LOCATION AND LAND USE	
2.1 Location and Access	2
2.2 Land Use	2
SECTION THREE - EXISTING INFORMATION	
3.1 Geology	4
3.2 Groundwater	4
3.3 Implications to Development	4
SECTION FOUR - TOPOGRAPHY AND DRAINAGE	
4.1 Topography	5
4.2 Drainage	5
SECTION FIVE - HYDROGEOLOGY	
5.1 Introduction	7
5.2 Surficial Geology	7
5.3 Bedrock Geology	12
5.4 Groundwater	17
SECTION SIX - SUMMARY AND CONCLUSIONS	
6.1 Summary	22
6.2 Conclusions	23
SECTION SEVEN - RECOMMENDATIONS	24

LIST OF TABLES

Table 5.1: Composite Textural Log of Subsurface Geology - Glacial Till	10
Table 5.2: Composite Textural Log of Subsurface Geology - Bedrock Units	15
Table 5.3: Hydraulic Conductivity of Glacial Till	18
Table 5.4: Hydraulic Conductivity of Upper Shale	21

LIST OF FIGURES

Figure 2.1: Location Access Plan	3
Figure 4.1: Distribution and Thickness of Muskeg	6
Figure 5.0: Drill Hole Locations	8
Figure 5.1: Particle Size Distribution - Glacial Till	9
Figure 5.2: Frequency - Thickness Distribution - Glacial Till	11
Figure 5.3: Bedrock Sub-Units	13
Figure 5.4: Particle Size Distribution - Bedrock Units	14

SECTION ONE

INTRODUCTION

Several areas in the vicinity of Swan Hills, Alberta were identified through a constraint mapping process as exhibiting few or no significant environmental constraints to development of a special waste management facility. Constraint mapping is based on published geologic/hydrogeologic information, however, and due to the relatively remote location of the Swan Hills area, it was recognized in the early stages of mapping that published information may not provide sufficient detail to identify constraint-free areas to the degree of accuracy required. Of five sites tested in the Swan Hills area by on-site drilling, only the Windy Lake Site (W1/2 6-67-8-W5) exhibited geologic conditions considered suitable for development of a waste management facility. This report represents a summary of the final hydrogeologic report prepared for the Windy Lake Site. The text of the final report contains a greater level of detail than presented herein, and also contains maps and cross sections at the 1:2000 scale. All lithologic details from test holes and hydrogeologic information collected during on-site monitoring are appended in the final report.

SECTION TWO

LOCATION AND LAND USE

2.1 Location and Access

The Town of Swan Hills is located 220 kms northwest of Edmonton via Highways 16, 43 and 33 (Barrhead route). Travel time from Edmonton is approximately 2.5 hours.

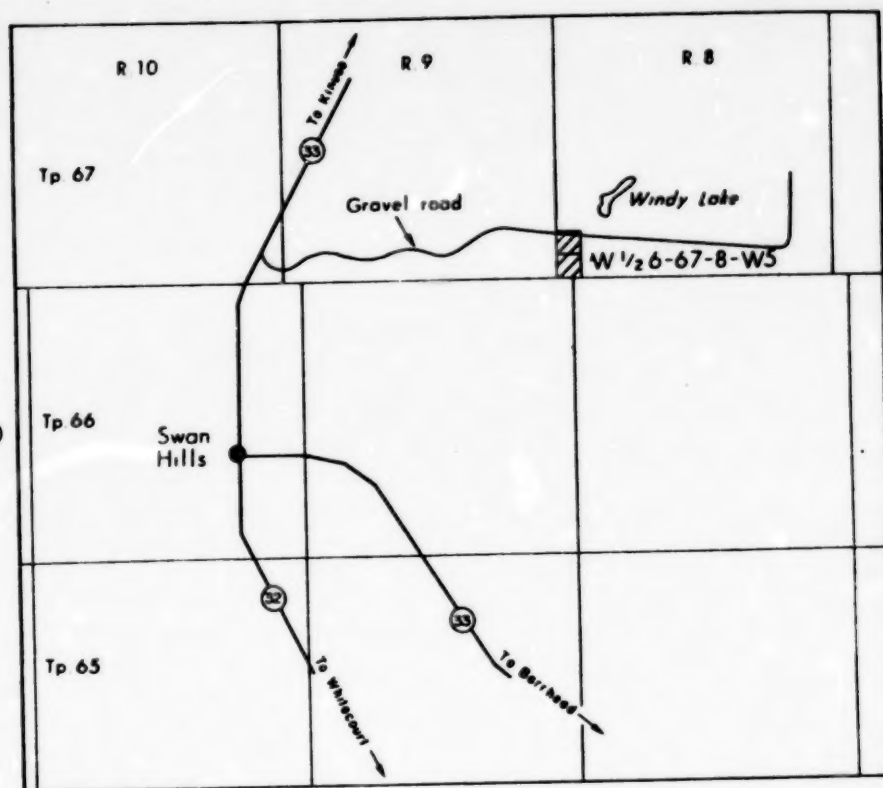
The Windy Lake Site is located 20 kms northeast of Swan Hills Townsite. Access is northward via the Kinuso Highway and eastward via gravelled back-country access roads (Figure 2.1). The back-country roads are traversible only with 4-wheel drive vehicles during periods of inclement weather.

Trails and cutlines provide access into the Windy Lake Site; these support 4-wheel drive traffic only, and are impassable under wet and soft ground conditions.

2.2 Land Use

Except for cutlines, the Windy Lake Site is occupied by pine and spruce forest. There are no pipelines or traplines, and the land is primarily wildlife habitat.

SCALE 1:250,000



SCALE 1:50,000

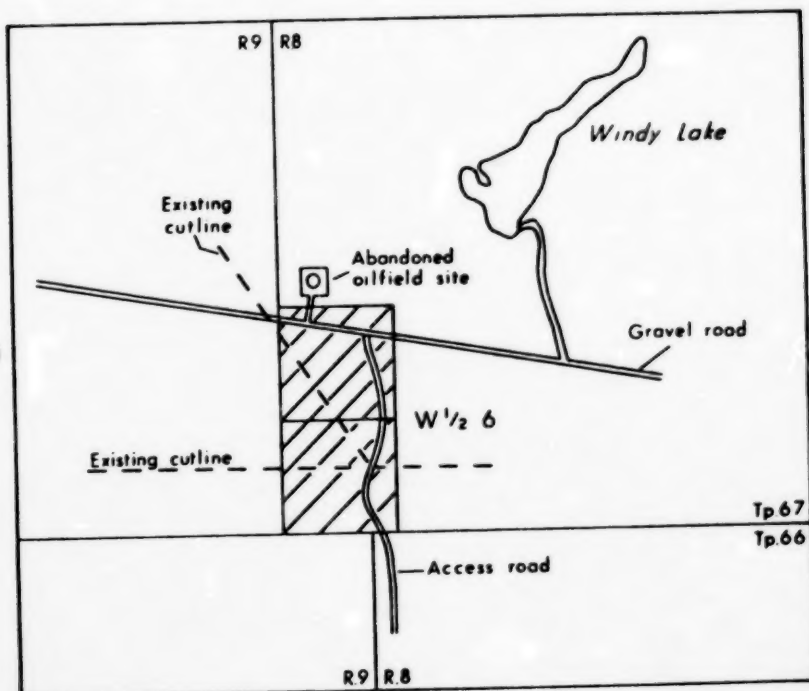


FIGURE 2.1. LOCATION ACCESS PLAN

SECTION THREE

EXISTING INFORMATION

3.1 Geology

Published map data indicate geologic deposits beneath the Windy Lake Site consist of glacial till with a hummocky moraine landform. The till overlies Cretaceous age sediments of the Paskapoo Formation (Scollard Member). Thick coal beds are typical of the Scollard, and it was considered that these must be absent, or at considerable depth, in order for the Windy Lake Site to be retained as a candidate site for the waste management project.

3.2 Groundwater

Based on published data groundwater yields from aquifers in bedrock are estimated in the range of 25-115 L/min, but such yields may require multi-aquifer completion. It was considered that if aquifers capable of such yields were present, they must be overlain by a sufficient thickness of impermeable geologic materials in order to be adequately isolated from the waste management facility.

3.3 Implications to Development

The existing published information indicated, prior to on-site testing, that significant hydrogeologic constraints to development may exist at the Windy Lake Site, and that site suitability would depend on the thickness and hydraulic characteristics of the glacial till cover. Since the available maps were constructed from a sparse data base in the remote area it was considered that limited on-site testing would be required initially in order to confirm the existence of constraints suggested by published data.

SECTION FOUR

TOPOGRAPHY AND DRAINAGE

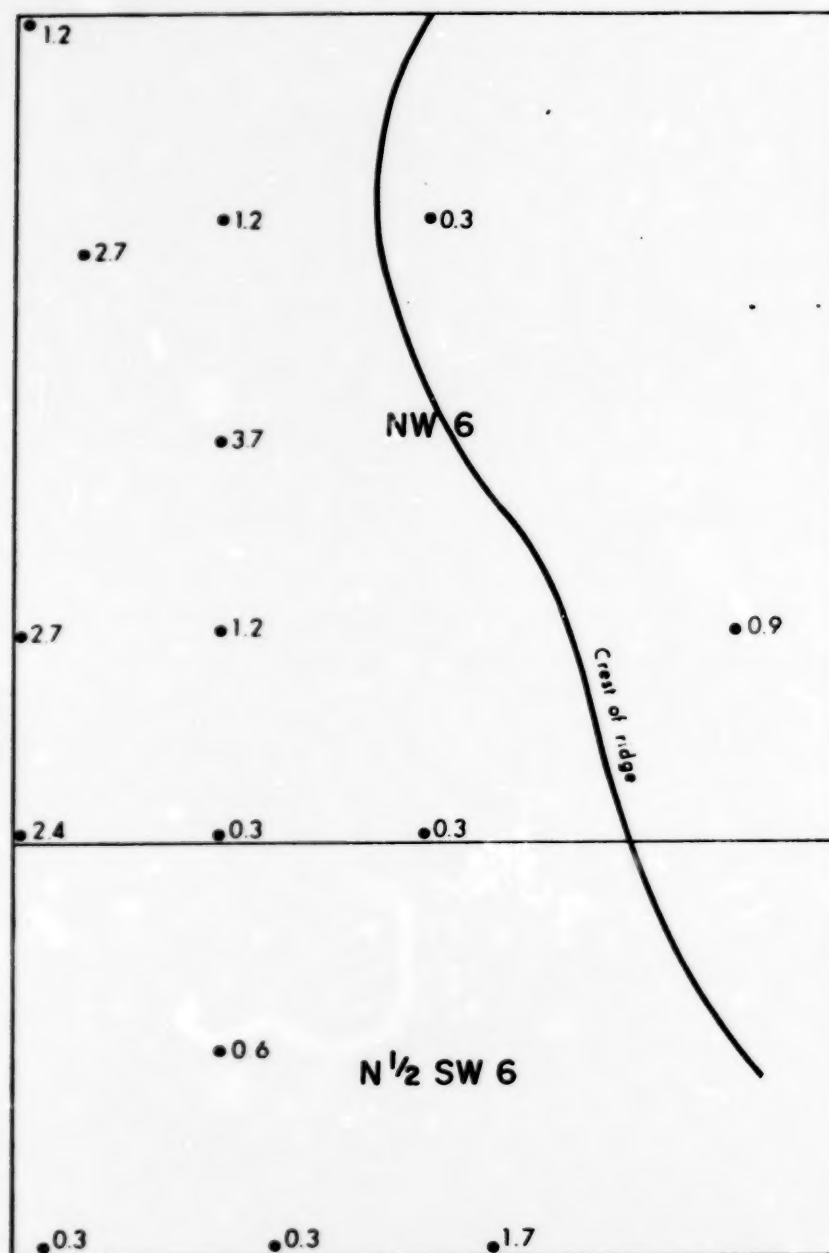
4.1 Topography

The topography of the Windy Lake Site is dominated by a centrally located linear ridge trending northwest-southeast across the site (Figure 4.1). The land surface falls gently westward and more steeply eastward; the Coutts River valley lies immediately east of the site, trending north-south parallel to the eastern boundary.

Topographic relief totals 37 metres, falling from a central high elevation of 1089 metres to 1052 metres (geodetic) along the eastern boundary.

4.2 Drainage

Surface drainage is poorly developed on the Windy Lake Site. The heavy forest and underbrush growth prevents any significant runoff, and surface water tends to accumulate in numerous depressional areas which are currently occupied by organic (muskeg) deposits. The peat materials are located mainly west of the bisecting ridge, and range up to 3.7 metres thick as indicated in Figure 4.1. Surface drainage courses are absent and the depressional areas will remain in the muskeg state until surface drainage is established. A preliminary report on drainage feasibility has been prepared by Alberta Environment staff.



Scale 1:6700

FIGURE 4.1. DISTRIBUTION AND THICKNESS OF MUSKEG.
Depth in metres.

SECTION FIVE

HYDROGEOLOGY

5.1 Introduction

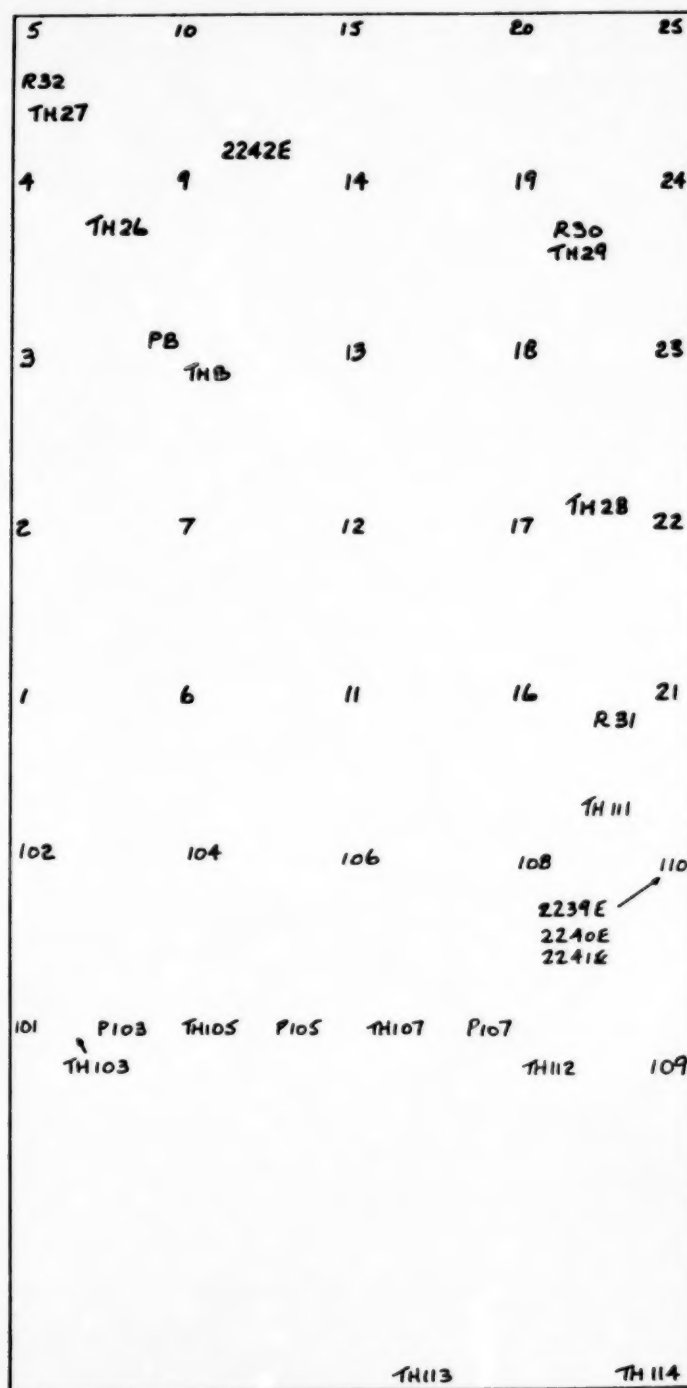
The geology to a depth of 18 metres beneath the Windy Lake Site was evaluated by drilling 43 dry auger test holes on a 200 metre grid. The grid covers all of NW6 and the northern portion of SW6 as indicated in Figure 5.0. A piezometer nest consisting of at least three piezometers completed to depths of 6, 12 and 18 metres was installed at each of 35 grid points.

The stratigraphy to depths greater than 18 metres was determined by rotary drilling or coring. Four rotary holes were drilled to depths ranging from 90 to 152 metres below surface, and two holes were cored to depths of 64 and 46 metres respectively. Two additional piezometers were completed at depths of 48 and 55 metres below surface. The locations of the rotary, core holes and deep piezometers are indicated in Figure 5.0.

5.2 Surficial Geology

Surficial deposits mantling the Windy Lake Site consist exclusively of uniformly clay loam-textured glacial till. Samples from two test holes were submitted to a laboratory for particle size analysis; samples from all other test holes were field-textured to estimate particle size distribution. Results of laboratory analyses are contained in Table 5.1 and graphically displayed in Figure 5.1.

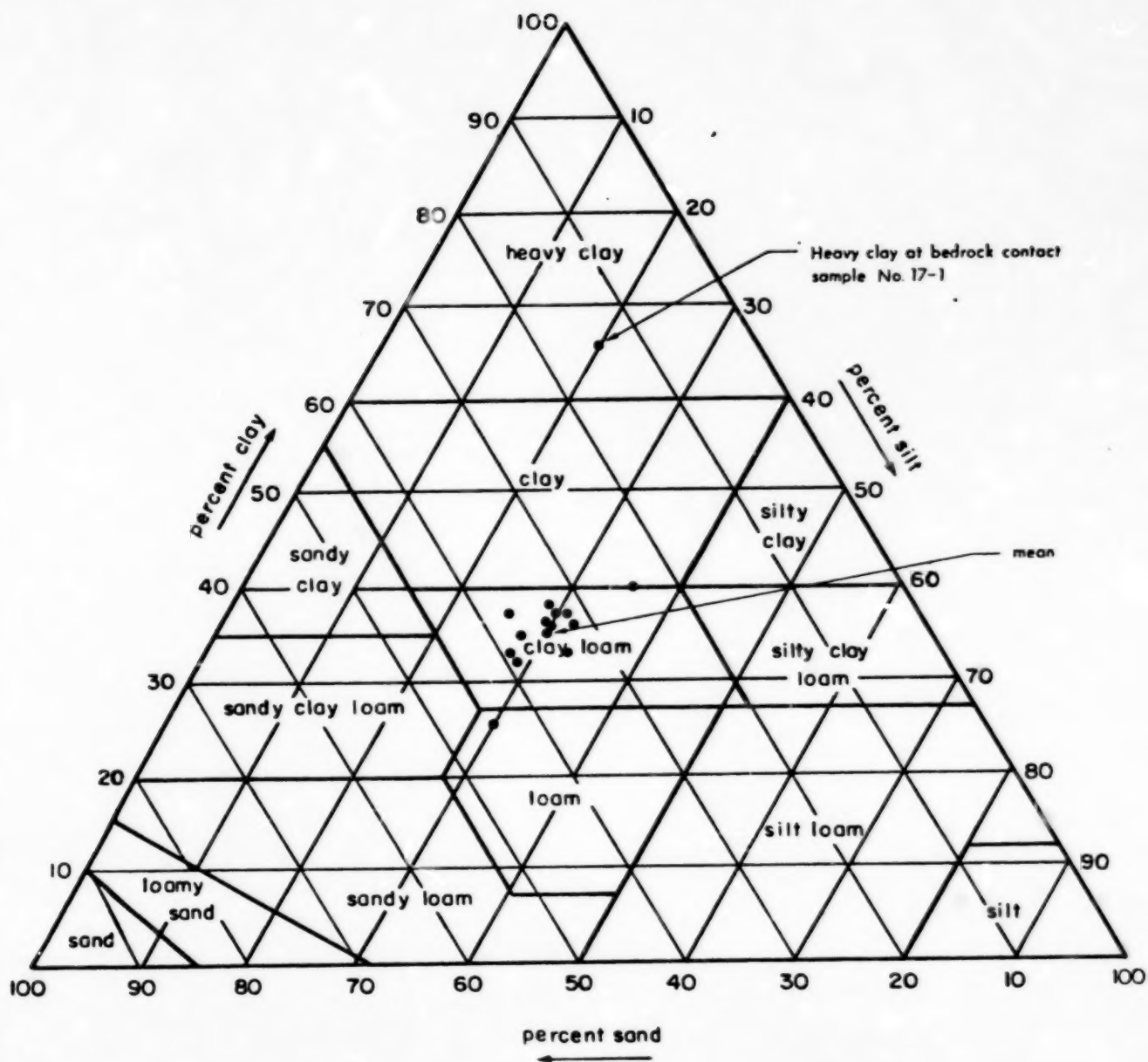
FIGURE 5.0: Drill Hole Locations



Legend

W1/2 Section 6 Tp 67 R8 W5th

- 101 Denotes test hole and piezometer location
- TH103 Denotes test hole only
- P103 Denotes piezometer only
- R32 Denotes rotary drilled test hole
- 2242E Denotes Alberta Environment drill hole



n = 14

mean = 34.8 % sand

30.1 % silt

35.1 % clay

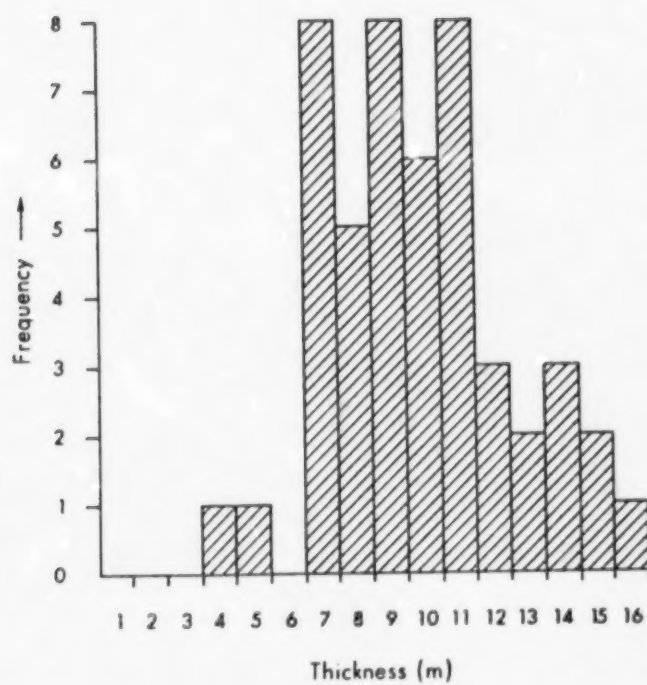
FIGURE 5.1. PARTICLE SIZE DISTRIBUTION - GLACIAL TILL.

Table 5.1: Composite Textural Log of Subsurface Geology -
Glacial Till

Description	Sample Depth	Texture	Test Hole
Glacial Till	1.5 m	CL	25
"	3.0	L, CL	25; 2
"	4.6	CL, CL	25; 2
"	6.1	CL, CL	25; 2
"	7.6	CL, CL	25; 2
"	9.1	CL, CL	25; 2
"	10.7	CL, CL	25; 2
"	12.2	C	25
Clay at Bedrock Contact	7.6	HC	17

As indicated in the Table, a heavy clay layer occurs frequently at the contact separating till from the underlying bedrock. This layer retains till-like characteristics but appears gradational between till and crushed bedrock (shale). For mapping purposes the lower clay unit has been included in the till thickness.

Glacial till mantling the Windy Lake Site ranges in thickness from 4.3 to 16.2 metres, with a mean of 9.9 metres. A plot of the frequency of recurring thickness classes is illustrated in Figure 5.2. The till contains occasional pebbles of quartzite, chert and granite, and inclusions of local bedrock materials including primarily shale and coal. Weathering effects have penetrated generally to a depth of three metres below surface; till within the weathered zone is brown or grey-brown as a result of oxidation and till beneath the weathered zone is dark grey.



N = 48
Range = 4.3 - 16.2 m
Mean = 9.9 m
St. Dev. = 2.6 m

FIGURE 5.2. FREQUENCY-THICKNESS DISTRIBUTION - GLACIAL TILL.

5.3 Bedrock Geology

5.3.1 Lithology

Bedrock beneath and adjacent to the Windy Lake Site consists of a Cretaceous-age sedimentary sequence of shale and sandstone. The bedrock sequence is separable into six sub-units as indicated in Figure 5.3; in view of a gentle structural dip to the southwest, sub-units B to E (inclusive) subcrop beneath the site. A brief description of each unit is as follows:

Unit A - Consists primarily of unconsolidated silt and sand. This material outcrops on topographically higher ground west of the Windy Lake Site and is tentatively considered the lower part of the Scollard Member of the Paskapoo Formation. The thick coal seams characteristic of the Scollard would be situated stratigraphically above Unit A, and would appear in the subsurface further west of the Windy Lake Site.

Unit B - Grey to green mudstone with soft, white bentonitic horizons and hard, white volcanic ash horizons. Particle size analyses indicate a texture ranging from loam to silty clay loam (Figure 5.4, Table 5.2). This unit subcrops beneath the western and central portions of the Windy Lake Site, and is in excess of 7.6 metres thick along the western margin. The lithologic description of Unit B is typical of sediments comprising the Whitemud Formation, to which this unit is tentatively correlated.

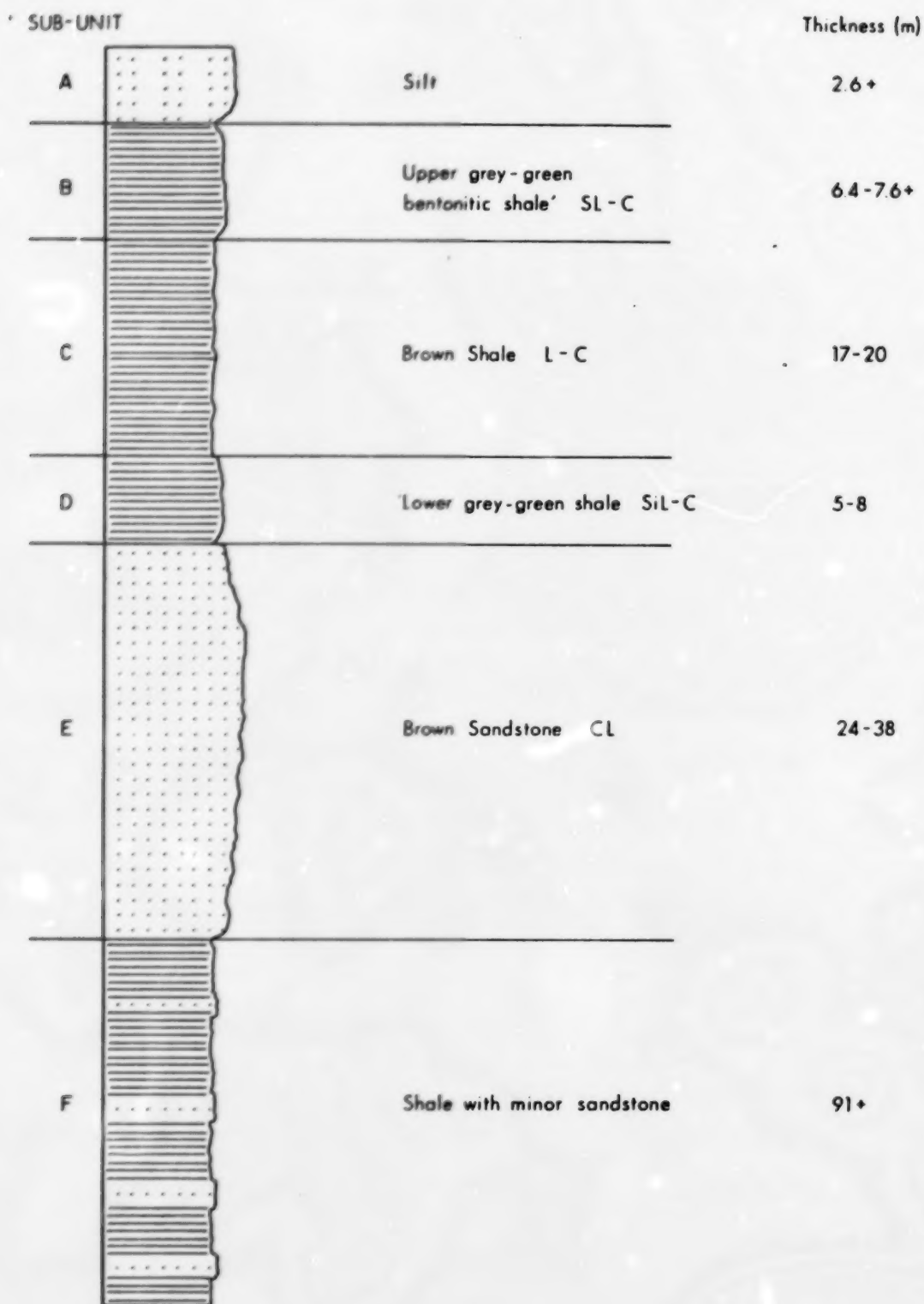
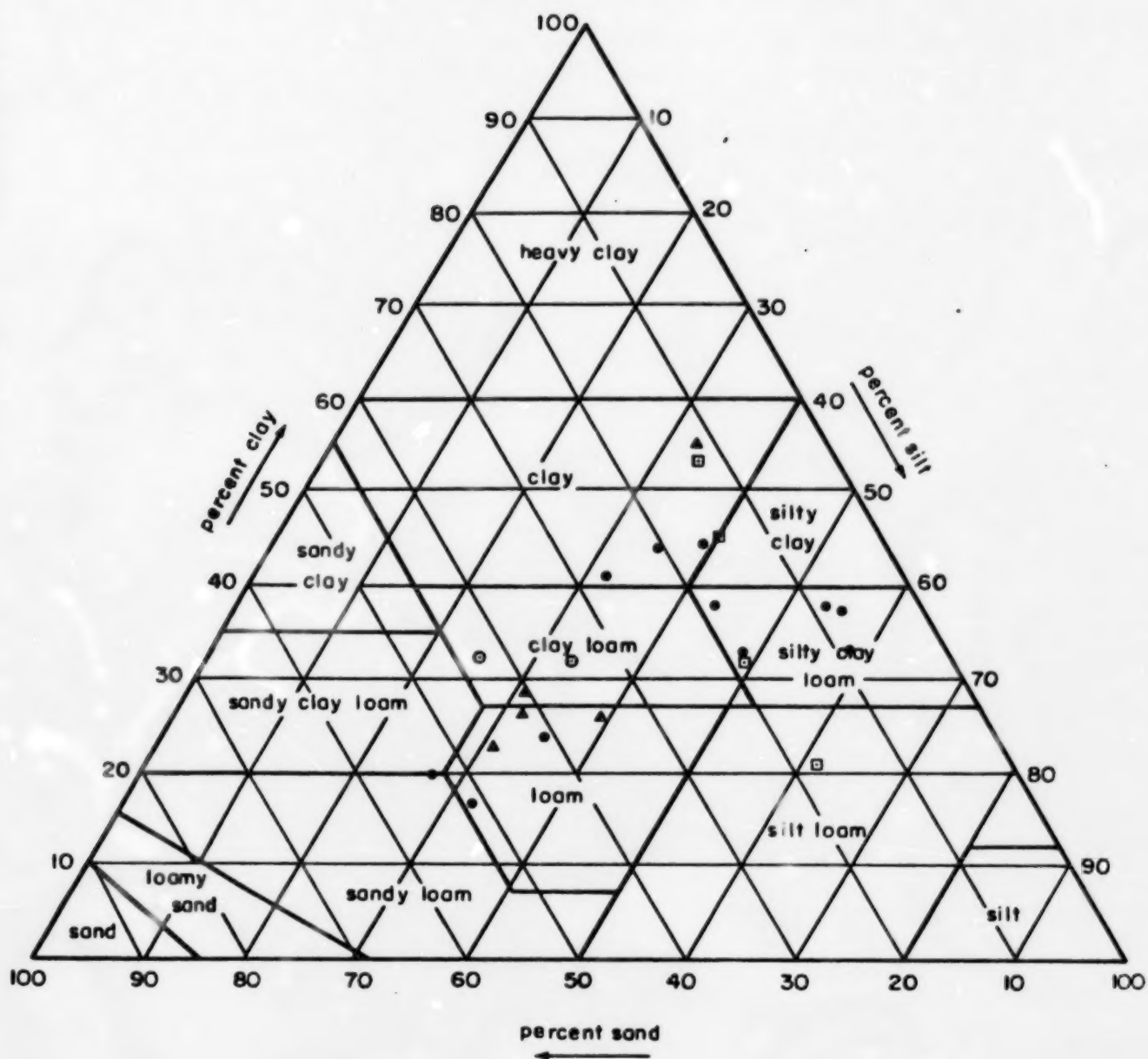


FIGURE 5.3. BEDROCK SUBUNITS.



LEGEND

- Upper Shale n=11
- ▲ Middle Brown Shale n=5
- ◻ Lower Shale n=4
- ◉ Sandstone n=2

FIGURE 5.4. PARTICLE SIZE DISTRIBUTION - BEDROCK UNITS.

Table 5.2: Composite Textural Log of Subsurface Geology -
Bedrock Units

Description	Sample Depth	Texture	Test Hole
Upper Shale (B)	8.2 m	L	17
"	8.8	C	17
"	9.8	SiCL	17
"	10.7	SiCL	17
"	12.2	L; SiCL	17; 2
"	12.8	SL	2
"	13.7	SiCL	2
"	15.2	C	2
"	16.8	SiCL	2
"	18.3	C	2
Brown Shale (C)	13.4	C	17
"	14.0	L	17
"	15.2	L	17
"	16.5	CL	17
"	17.4	L	17
Lower Shale (D)	13.7	C	25
"	15.2	C	25
"	16.8	SiCL	25
"	18.3	SiL	25
Sandstone (E)	14.6	CL	24
"	15.5	CL	24

Unit C - This unit is a brown tuffaceous or siliceous shale with intervening horizons of bentonite and argillaceous volcanic ash. The unit is similar to descriptions of the Battle Formation but the recorded thickness (17-20 metres) is greater than that normally reported for the Battle. Grain size analyses indicate a textural range from loam to clay.

Unit D - Similar in colours, lithology and texture to Unit B (mudstone).

Unit E - Fine- to medium-grained grey, unconsolidated sandstone, oxidized in parts. The unit ranges from 24-38 metres thick and subcrops in the extreme northeast corner of the Windy Lake Site. Two samples collected for particle size analysis reveal a clay loam texture. These sands are considered the upper part of the Wapiti Formation.

Unit F - This unit consists primarily of shale with minor interbedded sandstone. Minor coal seams, typical of the Wapiti, are situated in the upper part.

5.3.2 Bedrock Structure

Structure contours for the top and bottom of the brown shale (Unit C) indicate a variable stratigraphic dip to the west at the northwest corner and to the south along the southern boundary of the Windy Lake Site. The inconsistent dip direction indicates the stratigraphic sequence is locally flexured. The average structural dip at the bottom of the brown shale unit is southwest at 10 metres/km. Published information suggests a more gently southwesterly dip of 5 metres/km.

5.3.3 Bedrock Topography

The bedrock topography is a close reflection of surface topography, with a centrally located high, gentle westward and southward drops and a sharp eastward drop into the Coutts River Valley. Elevation range on the bedrock surface is from 1046 to 1076.1 metres (geodetic), for a total relief of 30.1 metres.

5.4 Groundwater

A groundwater investigation on the Windy Lake Site was designed to determine hydraulic characteristics within the till and underlying bedrock sediments. A total of 108 piezometers were installed for this purpose providing information as to hydraulic conductivity, watertable configuration, groundwater velocities and hydraulic heads from a potential aquifer identified in the subsurface.

5.4.1 Hydraulic Conductivity of Geologic Deposits

Hydraulic conductivity values for geologic materials were determined from single well response tests. Owing to perched groundwater conditions, however, piezometers completed in bedrock beneath the till are largely dry, and most of the response test results available are from the glacial till mantle where perched groundwater conditions exist.

Most of the hydraulic conductivity values obtained from till are based on response tests from piezometers completed at the 6 metre depth. Thirty-five values are available for glacial till with resultant conductivities ranging from 2.8×10^{-8} to 3.4×10^{-5} cm/s. As indicated in Table 5.3 the high (10^{-5}) value is from a poorly sealed piezometer and likely results from seepage past the seal; 33 of the values are in the order of 10^{-8} to 10^{-7} cm/s. The hydraulic conductivity values are typical of geologic materials normally considered impermeable.

Table 5.3: Hydraulic Conductivity of Glacial Till

Piezometer No.	Depth Below Surface (m)	Hydraulic Conductivity (cm/sec)
1W	6.17	4.1×10^{-8}
2W	6.25	6.0×10^{-7} (poor seal)
3W	6.08	(2.8×10^{-8})
4W	6.05	8.0×10^{-8}
5W	6.05	2.0×10^{-8}
6C	12.39	(3.2×10^{-8})
6W	6.21	5.5×10^{-8}
7W	6.29	4.7×10^{-8}
8W	6.18	3.2×10^{-8}
9W	6.38	1.0×10^{-7}
10W	6.32	2.0×10^{-7}
11C	12.30	6.0×10^{-8}
11W	6.21	2.2×10^{-7}
12W	6.12	4.6×10^{-8}
13C	12.28	6.1×10^{-8}
13W	6.11	2.3×10^{-6} (sl. weath)
14W	5.89	1.5×10^{-7}
15C	12.23	5.9×10^{-8}
15W	6.18	1.2×10^{-7} (sl. weath)
16W	6.09	4.4×10^{-8}
17W	6.24	4.8×10^{-8}
18W	6.06	2.2×10^{-7}
19W	6.18	5.7×10^{-8}
20W	6.12	6.0×10^{-8}
23W	6.28	3.5×10^{-8}
24S	6.28	4.8×10^{-8}
25W	6.21	1.0×10^{-7}
101W	6.15	4.3×10^{-8}
102W	5.98	7.3×10^{-7}
103W	6.14	(3.1×10^{-8})
104W	6.15	3.4×10^{-5} (poor seal)
105W	6.12	(2.8×10^{-8}) (sl. weath)
106W	6.12	5.4×10^{-8}
107W	6.23	3.5×10^{-8}
108W	6.18	8.7×10^{-8}
110W	5.93	Insuf. Water

NOTE: () - by extrapolation

Table 5.3: Hydraulic Conductivity of Glacial Till - Continued

Summary - Range and Frequency

<u>Range (cm/s)</u>	<u>Frequency</u>
$>1 \times 10^{-5}$	1 (104W - poor seal)
$5 - 9.9 \times 10^{-6}$	0
$1 - 4.9 \times 10^{-6}$	1 (13W - sl. weathered)
$5 - 9.9 \times 10^{-7}$	2 (2W - poor seal)
$1 - 4.9 \times 10^{-7}$	7
$5 - 9.9 \times 10^{-8}$	9
$1 - 4.9 \times 10^{-8}$	15
Insuf. Water	1 (110W)
Total	<u>36</u>

Response tests on piezometers completed in the upper shale (Unit B) indicate variable hydraulic conductivities in the range of 10^{-7} to 10^{-4} cm/s (Table 5.4). Most of the piezometers in this unit are dry, and the high conductivity values where groundwater is encountered indicate the shale is fractured.

Only one of 28 piezometers in the brown shale (Unit C) contains groundwater. A response test on this piezometer indicates a hydraulic conductivity of 6.3×10^{-6} cm/s, suggesting the piezometer tip intersects a water-bearing fracture.

No response tests were conducted on piezometers completed to levels below Unit C, as these were dry or contained static levels too low for testing.

5.4.2 Watertable Depth and Configuration

Owing to the low hydraulic conductivity of the till mantle, surface water, either precipitation or runoff, infiltrates at low rates and remains perched near the surface. The configuration of this perched watertable conforms closely to the surface topography, and ranges from less than 1 to greater than 6 metres below surface. The watertable is

deepest beneath the eastern margin of the Windy Lake Site where the steeply sloping topography promotes runoff to the east, and the opportunity for infiltration is limited. The watertable is shallowest in topographically level areas where runoff does not occur and depth of infiltration into impermeable till is limited.

The configuration of the perched watertable suggests that recharge occurs on the topographically high ridge which is centrally-located on the site, and that groundwater flow is radial from this ridge. It is unlikely that groundwater within the perched system actually flows, however, as the "watertable contours" simply reflect the surface topography. Assuming that groundwater does flow in response to the hydraulic gradients presented by the contours, the calculated velocity is in the range of 3 cm/century to 21 cm/year.

The maximum velocity results from combining the maximum hydraulic gradient with the maximum hydraulic conductivity in the velocity equation; this combination is never achieved in the hydrogeologic environment, however, and the velocity of 21 cm/year should be considered an unachievable maximum.

5.4.3 Groundwater Resources

Static groundwater levels in uncased rotary holes in the order of 46 to 50 metres below surface indicate the sandstone (Unit E) is only partially saturated. Air-lift tests from the sandstone indicated yields of up to 0.5 L/s. The sandstone has only limited production capability and long-term yields from the partially-saturated aquifer would likely be less than that indicated from the air-lift test.

Table 5.4: Hydraulic Conductivity of Upper Shale

Piezometer No.	Depth Below Surface (m)	Hydraulic Conductivity (cm/sec)
1E	18.11	Dry
1C	12.07	Dry
2E	18.35	Dry
2C	12.43	Dry
3E	18.50	2.7×10^{-7}
3C	12.47	2.6×10^{-7}
4C	12.16	Dry
6E	18.16	Dry
7E	18.39	Insuf. Water
7C	12.85	Dry
8E	18.18	Dry
9C	11.99	Dry
11E	18.22	8.9×10^{-7} ? (never recov)
12E	18.12	Dry
13E	18.26	Dry
16C	12.04	Dry
101E	18.19	Dry
101C	12.30	1.8×10^{-7}
102C	12.05	1.6×10^{-4} (poor seal)
103E	18.35	1.8×10^{-4}
103C	12.35	5.8×10^{-8} (never recov)
104E	18.52	Insuf. Water
104C	13.96	Dry
105E	18.11	Dry
105C	12.18	Insuf. Water
106E	17.37	9.1×10^{-4}
106C	12.32	2.2×10^{-7}
107C	12.27	Dry
108C	15.03	1.1×10^{-5}
109W	5.95	Insuf. Water

Summary - Range and Frequency

Range cm/s	Frequency
$>5 \times 10^{-4}$	1
$1 - 4.9 \times 10^{-4}$	2 (102C - poor seal)
$5 - 9.9 \times 10^{-5}$	0
$1 - 4.9 \times 10^{-5}$	1
$5 - 9.9 \times 10^{-6}$	0
$1 - 4.9 \times 10^{-6}$	0
$5 - 9.9 \times 10^{-7}$	1
$1 - 4.9 \times 10^{-7}$	4
$5 - 9.9 \times 10^{-8}$	1
Dry	16
Insuf. Water	4
TOTAL	30

SECTION SIX

SUMMARY AND CONCLUSIONS

6.1 Summary

Surficial geologic materials underlying the Windy Lake Site consist of a clay loam textured glacial till mantle with a mean thickness of 10 metres. The hydraulic conductivity of the till is very low, with most values ranging in the order of 10^{-8} to 10^{-7} cm/s. Because of the low hydraulic conductivity and lack of surface runoff, precipitation and snowmelt infiltrates to only limited depths resulting in a near-surface perched watertable. The perched watertable depth ranges from less than 1 metre below surface in topographically level areas to greater than 6 metres below surface on steep slopes. While groundwater will theoretically flow in response to gradients indicated by the perched watertable contours, it is unlikely that velocities in excess of several centimetres per century would be possible.

The surficial deposits are underlain by a sedimentary sequence of shale and sandstone. Based on descriptions provided in published data the subcrop materials beneath most of the site represent fine-grained sediments of the Whitemud and Battle formations. The deposits below this depth consist of an upper thick sandstone underlain by an interbedded sequence of shale and sandstone; these sediments are considered part of the Wapiti Formation. The Scollard Member sediments are absent from the Windy Lake Site but silt and sand outcrops immediately west resemble the lower part of the Scollard.

The Whitemud and Battle formations are dry for the most part. Where groundwater was encountered the response test data indicate fractures are present in the Whitemud. Core retrieved from rotary drill holes indicate that the more competent units in the Battle Formation are fractured.

A thick sandstone unit beneath the Whitemud-Battle sequence is only partially saturated. The upper saturated surface lies approximately 50 metres below surface and this is taken as the actual watertable. Air-lift tests recovered approximately 0.5 L/s from the sandstone, but longer term yields will likely be less than this value.

Geologic materials beneath the sandstone consist mainly of shale with sandstone interbeds and thin coal seams near the upper part.

6.2 Conclusions

A portion of the Windy Lake Site is suitable for development of a special waste management facility. The thick, relatively impermeable glacial till blanket will effectively retain any buried residual materials resulting from the waste treatment process, and will also retain any accidental or unscheduled discharge of treated or untreated waste materials while recovery measures are implemented.

SECTION SEVEN

RECOMMENDATIONS

The Windy Lake Site is considered suitable for development of a Special Waste Management Facility with the following recommendations:

- 1) The lack of adequate surface drainage presents the greatest development constraint to the proposed facility. The collection and accumulation of surface water in low-lying areas renders access and construction impossible on the site in its present condition. This aspect has been addressed by Alberta Environment staff and a preliminary report regarding drainage feasibility has been prepared.
- 2) The landfill and land-based treatment components of the facility should be located to take advantage of the following favourable hydrogeologic aspects of the site:
 - a) the presence of a 10 metre thickness of glacial till, and
 - b) the subcrop area of the bentonitic upper shale (Unit B).

The suitable area as defined totals 68 acres (28 hectares) on NW6, and 45 acres (18 hectares) on SW6. As the incidence of fracturing in Unit B appears higher beneath SW6, this area should be reserved for grade or above grade components of the facility.

- 3) All waste materials which require final disposal by landfill should consist only of residues resulting from the various treatment processes proposed. These may include incinerator residues, sludges, liquids or solids, but all wastes should be in a non-reactive form, immobilized by chemical fixation or otherwise permanently encapsulized.